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Cosmological simulations of the Milky Way

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Abstract. Recent simulations of forming low-mass galaxies suggests a strategy for obtaining realistic models of galaxies like the Milky-Way.

Cosmological simulations of galaxy formation are powerful tools for confronting the ΛCDM model with observational datasets. The increase in mass and spatial resolution and the improvement of sub-grid algorithms for star formation and feedback processes have recently resulted in simulated galaxies with realistic disk size and angular momentum content (Mayer *et al.* 2008; Governato *et al.* 2009a). However, simulated galaxies hosted in halos with masses $\sim 10^{12} M_{\odot}$ exhibit prominent bulges and structural parameters reminiscent of Sa spirals rather than of Sb/Sc galaxies. Surface densities at the solar radius are larger than that of the Milky Way (MW) by factors of a few and the more massive bulge produces a steeper rotation curve compared to that of the MW (Read *et al.* 2009). At halo masses $M_{\rm vir} > 2 \times 10^{12} M_{\odot}$ the predominance of hot-mode gas accretion counters the presence of a prominent star forming disk at $z = 0$, producing earlier-type objects resembling S0 galaxies (Brooks *et al.* 2009) and supporting recent estimates based on RAVE that yield $M_{\rm vir} \sim 10^{12} M_{\odot}$ (Smith *et al.* 2007).

Yet the solution to forming a realistic MW analog could be at hand. Recently we have performed galaxy-formation simulations for mass scales $< 10^{11} M_{\odot}$. By sampling these low-mass galaxies with several millions of particles, we achieve a mass resolution better than $10^3 M_{\odot}$ in the baryons, thus resolving individual molecular clouds. Star formation can now be tied to gas at molecular cloud densities ($\rho > 100$ cm^{-3}). A realistic, inhomogeneous interstellar medium is obtained that results naturally in stronger supernova outflows than when the standard star formation threshold ($\rho = 0.1$ cm^{-3}) is adopted. Such outflows efficiently remove the low-angular momentum baryonic material from the central region, suppressing the formation of a bulge and producing an object with a slowly rising rotation curve in very close agreement with observed dwarf galaxies (Governato *et al.* 2009b; see also Ceverino & Klypin 2009). We argue that comparable resolution of MW-sized galaxies will yield rotation curves and bulge-to-disk ratios appropriate for Sb-Sc spirals at $z = 0$. This requires increasing the number of particles employed by more than an order of magnitude.

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